

THE STATUS OF ELECTRIC MOTORCYCLES IN CHINESE TAIPEI

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ABSTRACT

With the advantages of energy savings and environmental protection, electric motorcycles have been designated a strategically important means of transportation by the government of Chinese Taipei. The Environmental Protection Agency (EPA) has mandated that 2% of all motorcycles sold in Chinese Taipei must be electric, and it is projected that about 3 million electric motorcycles (EM) will be on the road in 2010. This report provides a comprehensive survey of the development of electric motorcycles, covering background information, government activities, R&D projects, manufacturing, operation, the status of regulation and legislation, and a discussion of peripheral issues.

BACKGROUND

In 1994, imported energy was 95% of the total energy supply for Chinese Taipei, and total petroleum consumption was 52% of the total energy supply. From 1985 to 1994, the consumption rate of petroleum for motor vehicles rose by 14%, and the percentage of energy consumed by the transportation sector rose from 13% to 18%. According to the Intergovernmental Panel on Climate Change (IPCC) model, estimated CO₂ emissions in 1995 in Chinese Taipei were 162.5 million metric tons (mmt); within this, the total emissions of motorcycles were 1.83 mmt, or about 6.6% of the transportation sector and 1% of all CO₂ emissions.

Limited land, high population density, warm weather and shrinking distances between work and homes have combined to make motorcycles the most popular means of transportation in Chinese Taipei. Statistics reveal that the number of motor vehicles up to 1997 was about 15 million; among these, the motorcycle represented 10 million and produced 330 kt of carbon monoxide (CO) (12% of total) and 90 kt of hydrocarbons (HC) (8% of total) chemical pollution per year. The emission of CO and HC from two-stroke motorcycles was about 1.5 and 4.5 times that of four-stroke motorcycles, causing serious air pollution and degradation of living conditions. To reduce pollution, a multi-phase emission code was set up in early 1991, and although this induced strong resistance from the motorcycle industry, it also encouraged an indigenous manufacturing capability, improved technology and increased local market opportunities.

The basic strategies set up by Chinese Taipei's EPA are:

- 1) Administrative controls, which include strict standards, vehicle emission controls, economic incentives and suppression of vehicle growth.
- 2) Technical Controls, which include end-of-use controls, utilization of low-pollution fuels and improvement of transportation systems.

Based on the science and technology development policy of the Executive Yuan, a plan for development of an Electric Motorcycle (EM) was launched in 1998 under the supervision of the EPA. The major goal of this 4-year plan, with a budget of NT\$630

million, is to establish EM design technologies, fabrication capabilities, operation and maintenance guidelines, and regulatory and promotion networks.

A task force was established that incorporated the Ministries of Economic Affairs (MOEA), Transportation and Communication (MOTC), and Finance (MOF), as well as the National Science Council (NSC). The task force plans to sell 400,000 EMs annually by 2006, stimulating environmental protection, creation of a new industry, and reduction of energy consumption.

Environmental protection

The estimated number of EMs in 2010 is 3 million, or about one third of all motor vehicles in Chinese Taipei. At that time, the estimated reduction of pollution will consist of 42 kilotons (kt) of CO (2.8% of total) and 23.4 kt of HC/NO_x chemical pollution (2% of total). The estimated reduction in Chinese Taipei's contribution to global warming is 326 kt of CO₂ (0.2% of total). Table 1 compares pollution emitted by EMs and conventional Engine Type Motorcycles (ETM).

Table 1 Pollution Comparison of EM and Conventional Motorcycles

	Solid pollution	SO_x	CO	HC + NO_x	CO₂
EM pollution (g/km)	0.0147	0.038	0	0.0492	30
ETM phase 2 restriction (g/km) (enacted July, 1991)			4.5	3.0	57.18
ETM phase 3 restriction (g/km) (enacted July, 1998)			3.5	2.0	57.18

Energy savings

An EM consumes 130 watts/hour (W/h), or about half the energy consumed by an ETM. The estimated total energy savings made possible by EMs is 2,220,000 megawatt-hours/year (MWh/y), or about 0.75% of total electricity generation. This equals 245 KLOE (3% of petroleum annual sales in 1996). And the benefit of shift of peak load is about 4.2%.

Creation of win-win industry

Taking both economics and environment into consideration, the EM, a green product, is expected to be the major small transportation carrier in next century. An estimated production value for EMs of NT\$50 billion within 4 years will push Chinese Taipei's economy to be the global center of excellence for manufacturing of EMs.

Research and Development

The annual R&D fund sponsored by the EPA and Energy Commission (EC) is NT\$300 million. Major organizations involved in the project are the Mechanical Industrial Research Laboratories (MIRL), the Material Research Laboratories (MRL) and the Energy Resources Laboratories (ERL) of the Industrial Technology Research Institute (ITRI). A 4-year project running from 1999 to 2002 focuses on the following main areas.

Vehicle

The so-called third-generation EM, or advanced EM, is designed to fulfill several features, including:

- Low-weight design, reducing weight from 120 kg to 90 kg;
- Long-life battery, adapted from a lithium secondary battery rated for greater than 36,000 km;
- Matched driving system and energy management, for a driving range greater than 60 km;
- Quick-charging capability, with a 15 minute charge providing 30 km of use; and,
- Low-operating-cost, non-changeable battery, with operating cost of NT\$1.23 per mile.

Table 2. Comparison: Advanced and Conventional EMs

	Features		Advanced EM	Conventional EM
Performance	Max speed		55 km/hr	52 km/hr
	0-30m acceleration		4.8 sec	5 sec
	Climbing capability		20 kph@12deg.	10 kph@12deg.
	Driving distance	ECE 47	60 km	40 km
		Constant speed 30km/h	80 km	60 km

Weight less than 90 kg 119 kg **Accessibility** General charging @ECE47b 8 hr
 for 60 km 8 hr for 40 km Quick charging @ECE47b 15 min. for 30
 km **Battery** Type Lithium-ion Lead-acid Life 36,000 km 1-2
 Years
 Battery

In the near future, several kinds of battery can be used in EMs; Table 3 compares the type classes.

Table 3. Comparison of Batteries

	Lead-acid		Ni-Cd	Ni-MH	Li-ion
	General type	deep-discharge type			
Cost(NT/KWH)	2,200	5,000	11,000	15,000	8,000
Cycle life (Single Battery)	200	~500	NA	500 (c/3 80% DOD)	200 (80% DOD)
Use	UPS, engine-type vehicle	General-type and electric vehicle	Small appliance, electric vehicle	Small appliance, electric vehicle	Small appliance
Features	Low cost, short life for deep charge and discharge	Low cost, long life for deep charge and discharge	Quick charge, low power density, with memory effect	Quick charge, high energy-density, with partial memory effect	Quick charge, high energy-density, long life, high cost
Status of Development	Not suitable for EM	Matured product used for EV	Matured product used for EM	Prototyping phase for EM	Prototyping phase for EM

Performance, weight and price are the factors to decide whether an EM can be practically marketed, and the main influence on these factors is the battery. The requirements for a high-performance battery are high energy density, high cycle-life and a good battery management system. In the domestic market, lead-acid batteries are still the most common, though there are a few of the Ni-MH type. For use over the long term, advanced batteries must meet the following criteria:

- Energy density greater than 90 watt-hours/kilogram (Wh/kg)
- Power density greater than 200 W/kg
- Cycle life greater than 600 cycles
- Cost less than NT\$10,000/kWh

Tasks that remain for battery R&D include development of a protection circuit, a solid electrolyte, high performance, low-cost materials for electrodes, and a battery management system and state-of-charge indicator. A thorough analysis of the Lithium battery market is given in Table 4.

Table 4. SWOT Analysis for Lithium Battery Market

Strengths <ul style="list-style-type: none"> • Government policy reduces R&D risks • Retail battery enterprise already exists • Ems are under development • Local small-battery technique is matured 	Weaknesses <ul style="list-style-type: none"> • Local large-battery industry is still weak • Peripheral industry is incomplete • Raw materials rely on imports • Expertise and modular battery techniques are insufficient
Threats <ul style="list-style-type: none"> • Prototype products are on the market in Japan, the U.S. and France. • Cost and safety problems are still bottlenecks • Competition with other high performance battery-types is keen. 	Opportunities <ul style="list-style-type: none"> • Need from EM industry is urgent. • Market growth is rapid. • Li-ion battery is a new industry with great potential for growth

Motors and Controls

Table 5 shows the different motors used in EMs; if costs can be reduced to an acceptable level, DC brushless motors will become the best choice for EMs.

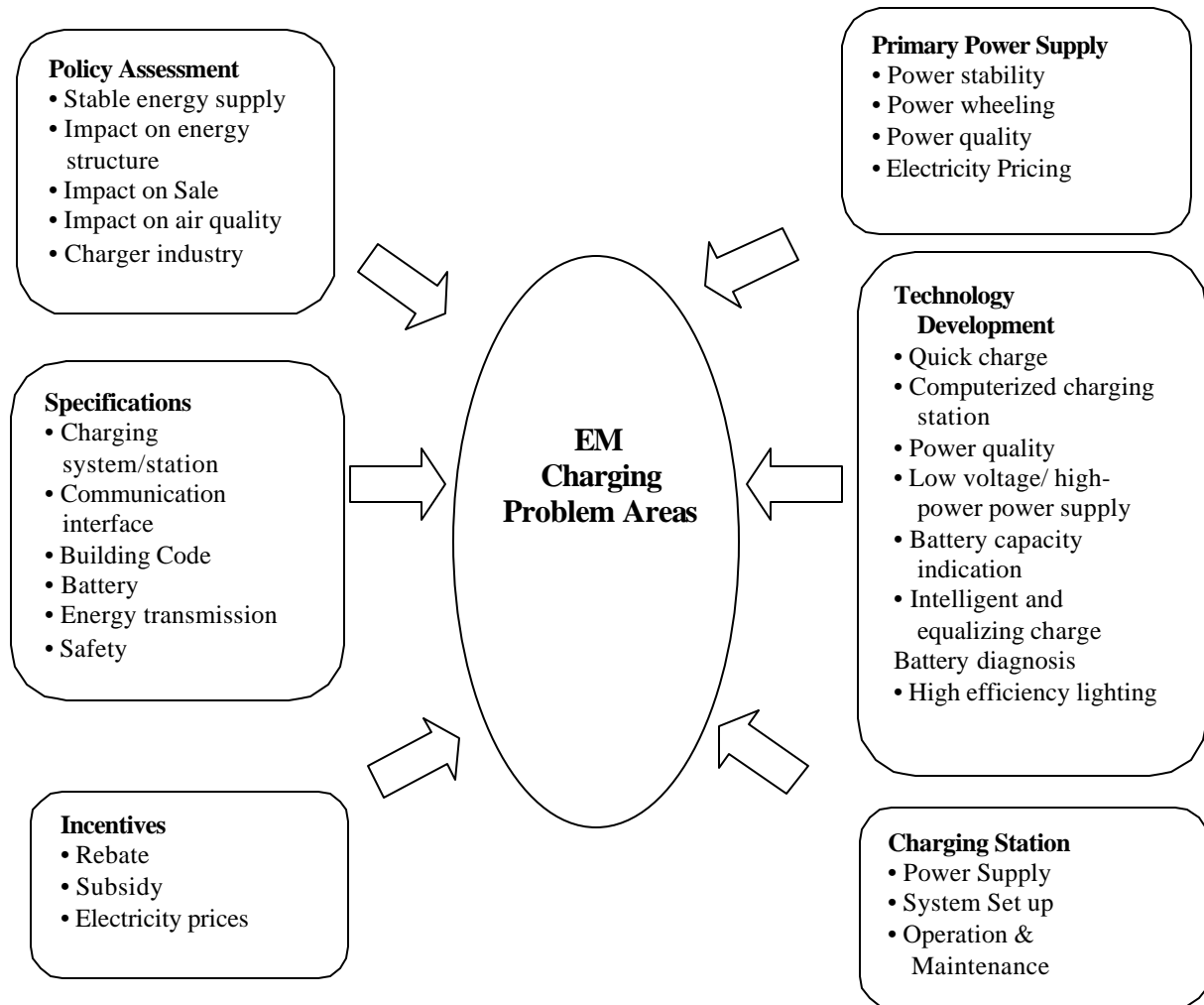
Table 5. Comparison of Motors and Controls

	DC brush motor	DC brushless motor	AC induction motor
Control method	Chopper control	PWM, square wave control	PWM, sine wave control
Configuration	Permanent magnet stator, wire-wound rotor, brush commutation complicate configuration	Wire-wound stator, permanent-magnet rotor, simple configuration	Wire-wound stator, permanent magnet rotor, simple configuration
Efficiency	Low	High	Medium
Cost	Medium	High	Low
Operating Characteristics	Bad heat dissipation; Limited overload and over temperature	Good heat dissipation	Good performance for overload; High temperature operation
Use	Most motors used for small EV	Most motors used for EM, few for EV	Most motors used for EV

Charging Environment

Besides vehicle and battery core technologies, the provision of a safe, confident and cost-effective operating environment is also important. To establish a charging environment, a bunch of problems have to be considered. Figure 1 shows the problem areas related to it.

Figure 1. Problem Areas for EM Charging



To establish a user-friendly charging environment, the tasks remaining to be accomplished are:

- To develop a 6 kW quick charger;
- To develop a 600 W equalizing charger;
- To improve battery life and develop a battery management system;
- To optimize the charging model for different batteries;
- To set up the capability to test batteries and measure power quality;
- To develop assessment techniques for metropolitan charging environments;
- To develop regulations for charging stations and ground rules for allocation of stations;
- To develop ground rules for EM demonstrations, and
- To study the feasibility of commercialization.

Environmental Regulation

With regard to official promotion and use of incentives to encourage manufacturers to produce high-efficiency, low-pollution vehicles, experience in other countries has demonstrated that legislation against environmentally insensitive systems is the most effective action.

Regulations requiring the sale of EMs have been in place since 1995 and effective since January 2000 in Chinese Taipei. The percentage of EMs sold by local manufacturers or importers must be no less than 2% of total annual sales, and this percentage will be adjusted upward gradually. In addition, agencies have also begun preparing regulations on traffic control, high-pollution vehicles, charging station set-up, and tax reduction for EMs.

National Standards

The Bureau of Standards, Metrology and Inspection (BSMI) began preparing EM standards in 1998. Early standards covered only charging facilities, safety requirements, symbols and labels, inspection and testing of lead-acid batteries, performance testing for EMs, and a glossary of terminology etc. In 1999, however, the Automotive Research & Testing Center (ARTC) began preparing 14 draft standards for EMs, using international standards including ISO, SAE, JIS, JASO, JEVS, UL, ECE, EN etc. These standards are shown in Table 6.

Table 6. EM Standards

Title	References
General rules of testing for EMs	CNS 3105 & 3107, JEVS E101
Methodology for testing maximum speed of EMs	JEVS E102
Methodology for testing acceleration of EMs	CNS3107
Methodology for testing climbing ability of EMs	CNS3111, JEVS Z104
Methodology for testing range of EMs	CNS3105, JEVS Z103
Methodology for measuring energy consumption by travelling EMs	CNS3105, JEVS Z106, JEVS Z111
Methodology for testing energy economy to EMs	CNS 3105, JEV Z105
Methodology for testing life cycle of EM batteries	
Methodology for testing specific power and power density of EM batteries	JEVS D103
Methodology for testing specific energy and energy density of EM batteries	JEVS D702
Methodology for testing capacity of EM batteries	JEVS D701
Methodology for measuring the combined power of electric motors and controller	JEVS E107, E701
Methodology for measuring electric motors equivalent to the on-board state for electric vehicles	JEVS E701,E702
Test limits and methodology for measuring electromagnetic interference of charging and discharging in EMs	SAE J1113, J551

Subsidies

The price difference between an EM (body and battery) and a conventional motorcycle is NT\$17,350. The scope of subsidies is as follows:

- 1) a maximum of NT\$5,000 for vehicle bodies;
- 2) for lead acid batteries, NT\$10,000 can be applied twice per vehicle within 4 years, whereas for Ni-MH batteries, NT\$25,000 can be applied only once within 4 years; and ,
- 3) a maximum of NT\$6,000 for chargers.

From 1999 to 2002, the total budget for subsidies covered by the EPA Action Plan is NT\$5 billion; additional incentives that may benefit EM manufacturers include:

- 1) the Upgrade Plan for Traditional Industry, sponsored by the Industrial Development Bureau (IDB), which will provide NT\$750,000 per manufacturer to develop competitive products;
- 2) the R&D Promotion Plan for Medium-Small Enterprises, sponsored by Taipower, Chinese Petroleum Corporation and Taisugar, which provides 75% support for each project;
- 3) the IDB and the Development Foundation of the Executive Yuan provide 25% subsidy and 25% loan to promote development of leading technology products; and,
- 4) other development projects supported by the IDB and Energy Commission.

Rebates

To upgrade industry, a rebate scheme that encourages energy savings and pollution protection was initiated in 1991. Its features include reduced taxes on imported materials and equipment, shortening of the depreciation period for machine equipment, tax exemptions for equipment and technical investment, and low-interest loans.

Local Manufacturers

Since 1995, five Electric Scooter (ES) manufacturers received the subsidy from EPA for about 2545 ESs. As for Electric Bicycles (EB), there are about 13 manufacturers locally, and the scope of manufacturing is summarized in Table 7.

Table 7. Local Electric Bicycle Manufacturing

Weight	Battery	Max speed	Range	Price	Units sold annually per manufacturer	Export are as
23–31 kg	Ni-Cd, Lead acid	20–25km/h	25–40kKm	US\$370 –660	2,000–10,000	Europe, U.S., Japan, PRC

CONCLUSION

In terms of policy, techniques, administration and marketing, the EM industry in Chinese Taipei is still in its inception phase; adapting other countries' experience may speed development. Technically, battery technology is the essential bottleneck to overcome, while practically, the ultimate task is to establish a feasible fabrication and operation environment.

REFERENCES

- Joseph, Ping-Ting Hsu. 1998 "Action Plan of EM Development." *Power Electronics Technology*, No.44, –11.
- James, Yin-Chin Wu. 1998 "Promotion of Electric Vehicle Systems an Innovative Perspective." *Power Electronics Technology*, No.44, 12–17.
- Ban-Chang Liao. 1998. "Domestic battery requirement and bottle neck of EM." *Power Electronics Technology* No.44, 8–13..
- Kuo-En Chang, Weir-Mirn Hurng and Ching-Yih Yao. 1998. "The Development of Secondary Battery for EM." *Power Electronics Technology*, No.44, 39–43.
- Chien-Tung Liu. 1998. "The Development and Application of Lead Acid Battery for EM," *Power Electronics Technology*, No.44, 54–64.
- Energy Commission/Mechanical Industrial Research Laboratories. 1999. "Development Plan for 3rd Generation EM."
- Energy Commission/Energy & Resources Laboratories. 1999. "Development Plan of Power Supply System for EM."

Bureau of Standards, Metrology and Inspection/Automotive Research & Testing Center Report. 1998. "Study on the EM Standards."

Bureau of Standards, Metrology and Inspection/Automotive Research & Testing Center Report. 1998. "Study on the Component Inspection and Safety Standards for Motor Vehicles."

EPA/Energy & Resources Laboratories. 1999. "The Assessment Plan of Quick Charging Station and Demonstration."

Industrial Development Bureau/Mechanical Industrial Research Laboratories. 1998. "International and Indigenous Development status of EM."

EPA. 2000. "Summary on the Subsidy Application for Purchasing EM."